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Simulations of vortical flow using an unbounded, regularized particle-mesh based vortex method

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In the present work we use an unbounded vortex method to perform direct numerical simulations of vortical flow. The method uses a recently developed unbounded Poisson solver[1], which is based on regularized Greens functions to obtain high order convergence. By simulating vortical flows with unbounded conditions we are able to: minimize the size of the computational domain, avoiding the effect of periodicity and thus performing simulations at high Reynolds number. The high order Poisson solver has been implemented in an unbounded particle-mesh based vortex method which uses a re-meshing of the vortex particles to ensure the convergence of the method. Furthermore, a re-projection of the vorticity field is performed at each time step to ensure a divergence free vorticity field.

The primary focus of the presentation is a detailed analysis of the vorticity topology obtained from numerical simulations of vortical flows. The deformation and alignment of vorticity (see Fig. 1) has been identified as an essential process in the characteristic energy cascade of turbulence. As the vorticity is stretched into sheet- and tube-like structures, the conservation of angular momentum constitutes an energy transfer between different length scales of the flow. The alignment of vorticity is also directly related to other phenomena in fluid dynamics such as sound generation. Thus an in depth knowledge of vortex deformation and alignment is essential for multiple disciplines in fluid dynamics.

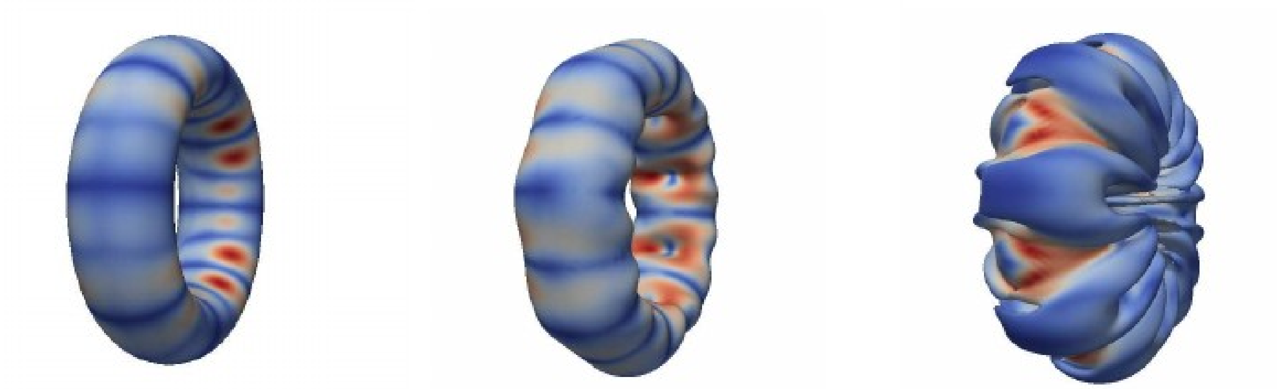

Figure 1: Simulation of a single vortex ring at a circulation based Reynolds number of 10.000. The vortex ring motion is from left to right. The pictures show the evolution of a single isosurface of the vorticity colored by the mis-alignment of the vorticity and the second eigenvector of the strain rate tensor.

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[1] Hejlesen et al., *J. Comp. Phys.* **252**, (2013).

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